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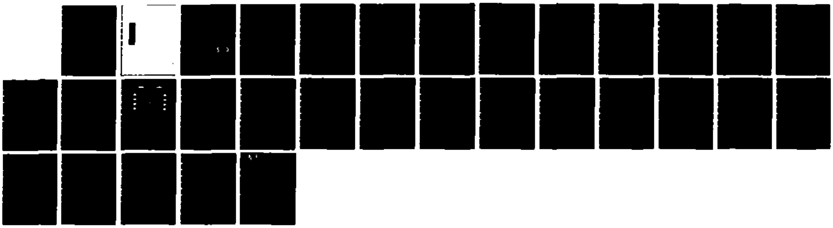

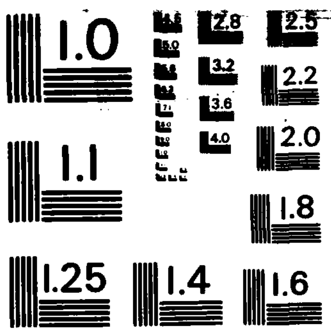

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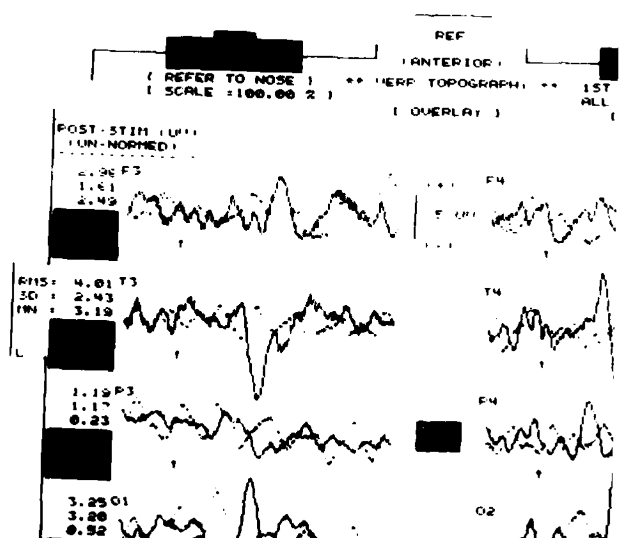

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CEREBRAL LATERALITIES AND INDIVIDUALIZED INSTRUCTION

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To ascertain whether cerebral lateralities can be considered aptitudes or individual difference measures within an aptitude-treatment-interaction (ATI) framework, hemispheric asymmetries and cognitive psychometric tests were administered to 50 right-handed, Caucasian, male Navy recruits. Principal factor analysis with varimax rotation were computed for these measures. A major portion of the variability in the data was attributed to cerebral lateralities either acting independently or interactively

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) with cognitive attributes. Their proven construct validity and importance as individual difference indices suggest that hemispheric asymmetries can be considered "aptitudes" within an ATI context. However, a number of conceptual problems, in addition to methodological difficulties, may limit the pedagogical payoff from ATI and asymmetry research.

FOREWORD

This research was performed under independent research work unit ZR000-01-042.027 (Cognitive Factors in Learning and Retention) under the sponsorship of the Chief of Naval Material (Office of Naval Technology). The general goal of this work unit is to investigate cognitive factors, and their associated processes, involved in learning, retention, and instruction.

The results of this study are primarily intended for the Department of Defense training and testing research and development community.

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SUMMARY

Background and Problem

Aptitude-treatment-interaction (ATI) assumes that different manners of instruction can be prescribed for types of students having specific aptitude profiles. It attempts to identify aptitudes that are useful for selecting instructional techniques to maximize student learning.

Cerebral lateralities refer to differential processing in the left and right cerebral hemispheres of human intact brains. Almost all behavioral dichotomies have been associated to specializations of left and right hemispheres. However, many times there is little or no empirical support to substantiate these and other speculations. It is difficult to separate fact from fantasy and to make recommendations for instructional research, development, and implementation.

Objectives

To make significant contributions to a prescriptive science of adaptive instruction, several assumptions must be empirically proven as valid: (1) normal individuals vary in their cerebral asymmetries, (2) these individual differences are associated with complex cognitive activity, and (3) individuals with distinct cerebral lateralities will benefit differentially from alternative instructional techniques. This study addresses the first two of these assumptions.

The objectives of this research were to (1) establish statistical linkages between hemispheric asymmetries and cognitive functioning, (2) provide converging support that both hemispheres play prominent parts in complex cognitive activity, and (3) determine the importance of cerebral lateralities for instructional research and development.

Approach

Visual, auditory, and bimodal event-related potentials (ERPs) were recorded from 50 right-handed, male, Caucasian Navy recruits from the Naval Training Center, San Diego. Hemispheric asymmetry indices were derived for corresponding brain sites and 11 psychometric tests of different cognitive attributes were administered. Principal factor analysis with varimax rotation were computed for asymmetry and cognitive measures.

Results

A major portion of the variability in the data was attributed to brain asymmetry measures either acting independently or interactively with cognitive measures. Some factors suggest that ERPs and cognitive characteristics contribute to or define the same underlying independent dimensions (i.e., they weight the same factors, implying that they are related). Some of the results of the varimax rotation seem to indicate that complex cognitive processing (i.e., tolerance of ambiguity, category width, general aptitude, spatial ability, logical reasoning, and field-independence/field-dependence) is statistically linked with visual, auditory, and/or bimodal cerebral asymmetries in the frontal, parietal, and/or occipital areas.

Discussion and Conclusions

1. The results established the construct validity of specific cerebral asymmetries as indicators of particular cognitive styles, abilities, and aptitudes. Brain asymmetries accounted for more of the variability among the subjects than did the cognitive attributes, which established the importance of lateral asymmetries as individual difference measures. For both of the preceding reasons, cerebral asymmetries can be considered "aptitudes" within an ATI framework.

2. Even though this has been empirically established, an important theoretical and practical question still remains to be answered: How can this asymmetry information be used to produce ATIs for prescribing differential instructional strategies to optimize student learning? One simplistic possible approach would be to adapt instructional strategies to conform to a learner's preferred mode of cognitive processing as indicated by cerebral lateralities (i.e., present material in the medium that is most congruent with a student's major manner of processing).

3. Probably both cerebral hemispheres contribute to complex cognitive activities, but it is not known which of the dichotomies is truly basic, fundamental, or prime in the sense that it is essential to the comprehension of the others (i.e., serial vs. parallel processing, analytical vs. global reasoning, propositional vs. analog symbolizing).

4. A salient conceptual difficulty dealing with the degree of cooperation, division of labor, and time sharing between the hemispheres in performing complex cognitive tasks must be resolved. Cooperative interaction models maintain that both hemispheres can execute a function equally or unequally well--but when do they actually contribute to the function? Negative interaction models of hemispheric asymmetry assert that both sides can execute certain functions; however, they typically suppress or inhibit the activity of the other through cortical or subcortical mechanisms--is this done unilaterally or bilaterally?

5. Theoretical or conceptual problems, in addition to methodological difficulties, may limit the practical payoff from ATI and asymmetry research. Even if different instructional techniques are designed and developed to draw on different asymmetries, the cerebral lateralities may not be exclusive. Different cognitive and cerebral attributes contribute more or less to performance at distinct stages of learning; consequently, there is not enough stability for adaptation.

6. It may be impractical to design and develop distinct instructional strategies to interact with cerebral lateralities. Lack of consistent and categorical results and conclusions concerning lateralities contribute to the ambiguity. To employ hemispheric asymmetries as individual difference measures for establishing ATIs may really be at this time the seeking of truly elusive interactions as well as science fiction.

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INTRODUCTION

Background and Problem

Several psychologists (e.g., Bracht, 1970; Cronbach, 1957, 1967; Cronbach & Gleser, 1965; Cronbach & Snow, 1969; Gagné, 1967; Glaser, 1967, 1972, 1976; Jensen, 1967, 1968) have asserted that no single teaching method is best for all students. If this is true, then students will be able to reach educational goals more efficiently when instructional procedures are adapted to individual differences. This would be possible if instructional treatments were accommodated to premeasured student aptitudes. According to Cronbach (1957, p. 681), it is best to "design treatments not to fit the average person, but to fit groups of students with particular aptitude patterns," or conversely, to "seek out aptitudes which correspond to (interact with) modifiable aspects of the treatment." In this context, aptitude is "any characteristic of the individual that increases (or impairs) his probability of success in a given treatment"; and treatment, "variations in the place or style of instruction" (Cronbach & Snow, 1969, p. 7). Aptitude includes any index of individual difference that distinguishes among students and treatments with respect to learning outcomes. It does not refer to general and mental ability (Snow & Salomon, 1968). As used in the literature, though, aptitude does indicate a rather enduring trait from which extrapolations are made concerning appropriate teaching treatments (Cronbach & Snow, 1969). However unintentional, this trait aspect of aptitude connotes a tendency that is relatively stable over short intervals (Tobias, 1976).

Cronbach (1967) discussed three models for accommodating instruction to specific students. The first involved simply manipulating the pace of teaching; the second, tracking homogeneous types of students who were given general treatments derived from instructional macrotheories (i.e., those entailing decision rules that prescribe feedback, prompting, reinforcement, etc.); and the third, designing instructional treatments as a function of how students normally acquire and manipulate material. The last model is much more accommodating in that it permits the modification of not only teaching treatments, but also student cognitive aptitudes. For the most part, Cronbach's models stressed pretask instructional adaptation (Tennyson, 1975); that is, they presumed that instructional treatments can be determined from empirically established aptitude measurements taken before the actual learning situation and that regression equations can be derived for assigning certain types of students to specific instructional treatments.

Aptitude measurements can be used for adapting instructional treatments to student characteristics only if aptitudes and treatments interact (Cronbach, 1967; Cronbach & Gleser, 1965; Cronbach & Snow, 1969, 1977); that is, aptitude measures must be developed to predit which individuals will learn best from specific instructional treatments. If such measures are available, then teaching treatments can be prescribed for types of students having specific aptitude profiles. This can be facilitated by the ability to discriminate among instructional treatments to maximize their interactions with aptitude measures. Cronbach (1967) proposed a comprehensive program of research to identify aptitudes that interact best with specific treatments. This area of research, which has been labeled aptitude-treatment-interaction or ATI, emphasizes identifying the aptitude measures that are useful for selecting instructional treatments to maximize individual attainment of specified educational objectives (Galser, 1972).

Supporting evidence is obtained when significant interactions are established between alternative instructional treatments and individual differences or personological variables. In ATI research, the personological variable is defined as any measure of individual characteristics (e.g., IQ, scientific interest, aptitude, anxiety) (Bracht, 1970). ATIs are usually sought in educational research by employing two-by-two factorial analysis of variance experimental designs. It is hoped that one personological variable correlates significantly with learning performance under one instructional treatment and the other personological variable correlates significantly with learning performance under the other instructional treatment:

> An ATI exists, in effect, when the regression of outcome under treatment A, upon certain pretreatment information (e.g., aptitude measures), differs in slope from the regression for the same variables under treatment B. (Cronbach & Snow, 1969, p. 4)

To increase the likelihood of obtaining a significant disordinal interaction, the relationship between the two personological variables should be low or should approach nonsignificance. Disordinal interactions exist when the regression lines for instructional treatments intersect within the range of the aptitude measures or other personological variable under investigation. This information is used to prescribe teaching treatments for students as follows: To obtain optimal student performance, learners whose aptitude measures are to the left of the intersection point of the regression lines are allotted one instructional treatment, while those whose aptitude measures are to the right of that point are allotted the other instructional treatment (Berliner & Cahen, 1973; Cronbach & Snow, 1969; Snow & Salomon, 1968). Although Glaser (1972) asserted that only disordinal interactions should be used for assigning teaching treatments to students as a function of their aptitude measures, Berliner and Cahen (1973) and Snow (1976) proposed that ordinal as well as disordinal interactions have utility for assigning treatments to students with different aptitudes. Ordinal interactions exist when the regression lines for instructional treatments do not intersect within the range of the aptitude measure or other personological variables under investigation. To identify ordinal and disordinal interactions, consideration must be given to the correlations between student performance and aptitude and to the regression lines or slopes for different treatments.

Much clinical and experimental evidence (e.g., Allen, 1983; Bryden, 1982; Helligie, 1980; Hillyard & Kutas, 1983) demonstrates differential processing in the left and right cerebral hemispheres of humans' intact brains. Although there is considerable consensus concerning the existence of these asymmetries, their specific contributions to particular cognitive functions are still very much debatable and continue to be the object of scientific investigation. This prolonged interest in hemispheric asymmetry has been accompanied by increased speculation about the exact nature of laterality and its implications for human performance. It has become popular to associate almost all behavioral dichotomies to specializations of the left and right hemispheres. Theoretical assertions have been that the left hemisphere is superior for verbal, analytical, sequential, and logical tasks, and the right hemisphere is superior for spatial, integrative, simultaneous, and intuitive tasks. Many times, there is little or no empirical support to substantiate these speculations. Consequently, it is very difficult to separate facts from fantasy in the asymmetry area as well as to make recommendations for instructional research, development, and implementation. This is especially true in light of the several, substantial, unresolved, conceptual issues that are crucial to hemispheric laterality (Helligie, 1980).

It is paramount to employ many methods and subject samples to converge on the true nature of the cognitive processing in the cerebral hemispheres. In all likelihood, where hemispheric specialization does manifest itself, it is not absolute, but relative. It seems reasonable to hypothesize that, in intact brains, processing resources demanded by complex cognitive tasks are contributed by both hemispheres, which intermittently interact and share the load. What are the implications of hemispheric asymmetries for instructional research and development? Can cerebral lateralities be considered aptitudes or individual difference measures within an ATI framework? It seems reasonable to expect cerebral asymmetry and individual difference disciplines to capitalize on the scientific study of their relationships. In order for this kind of research to make significant contributions to a prescriptive science of adaptive instruction, the following assumptions must be empirically proven as valid.

1. Normal individuals vary in their cerebral asymmetries.

2. These individual differences are associated with complex cognitive activity.

3. Individuals with distinct cerebral lateralities will benefit differentially from alternative instructional treatments.

This study sheds some additional light on the first two of these assumptions.

Objectives

The objectives of this research were to (1) establish statistical linkages between hemispheric asymmetries and cognitive functioning, (2) provide converging support that both hemispheres play prominent parts in complex cognitive activity, and (3) determine the importance of cerebral lateral asymmetries for instructional research and development.

METHOD

Subjects

The subjects were 50, right-handed, male, Caucasian Navy recruits from the Naval Training Center, San Diego undergoing basic enlisted military instruction. Audition and vision of the subjects were empirically verified as normal.

Cognitive Characteristics Measured

The cognitive characteristics measured in the study are reported in Table 1. The six cognitive style and three ability tests were administered to each subject counterbalanced with the brainwave recordings. Scores for the two aptitude tests were obtained from Navy personnel records.

Cognitive styles (e.g., tolerance of ambiguity) are the dominant modes of information processing that people typically employ when perceiving, learning, or problem solving. Abilities are intellectual capabilities (e.g., verbal comprehension) that are general and pervasive to the performance of many tasks. Aptitudes are indices (e.g., mathematical or mechanical aptitude) used to select personnel to perform tasks that demand specific skills and to find the right person for a certain job or school.

Table 1

Cognitive Characteristic Measures

Cognitive Characteristic	Description	Measurement Instrument
Cognitive Styles		
Field independence vs. field dependence (FILDINDP)	Analytical vs. global orientation	Hidden figures test, Part I (Ekstrom, French, Harman, & Derman, 1976).
Conceptualizing style (CONCSTYL)	Span of conceptual category	Clayton-Jackson object sorting test (Clayton & Jackson, 1961).
Reflectiveness-impulsiveness (REFLIMPL)	Deliberation vs. impulse	Impulsivity subscale from personality research test, Form E (Jackson, 1974).
Tolerance of ambiguity (TOLRAMBQ)	Inclined to accept complex issues	Tolerance of ambiguity scale from self-other test, Form C (Rydell & Rosen, 1966).
Category width (CATEWIDH)	Consistency of cognitive range	Category width scale (Pettigrew, 1958).
Cognitive complexity (COGCOMPX)	Multidimensional perceptions of the environment	Group version of role construct repertory test (Bieri, Atkins, Briar, Leaman, Miller, & Tripodi, 1966).
Abilities		
Verbal comprehension (VERBCOMP)	Understanding the English language	Vocabulary test II (Ekstrom et al., 1976).
Visualization (VISUAL)	Manipulating spatial patterns	Surface development test (Ekstrom et al., 1976).
Logical reasoning (LOGIREAS)	Deducing from premise to conclusion	Nonsense syllogisms test, part I (Ekstrom et al., 1976).
Aptitudes		
General aptitude (GENRAPTD)	Comprehending language, solving arithmetic problems, and visualizing objects in space	Word knowledge subtest, arithmetic reasoning subtest, and space perception subtest (AFQT), Armed Services Voca-Aptitude Battery.
Reading comprehension (READCOMP)	Understanding English words and prose passages	Gates-MacGinitie reading test, level D, Form 1 (Gates & MacGinitie, 1965).

Instrumentation

Data were acquired on a field-portable computer system[1] that included a Data General NOVA 2/10 central processing unit (CPU, 32K memory); a dual-drive floppy disk unit (Advanced Electronics Design, Inc., Model 2500); an optically isolated and multiplexing EEG unit with bandpass set for 0.2-30 Hz; and a videographic display unit, integrated into the CPU, that presented visual stimuli to the subjects and displayed the analyzed ERP data. The signal sampling rate for each channel of the analog EEG waveforms was set at 500 Hz. Permanent storage of all video information was obtained from a video hard copy unit (Tektronix Model 4632).

Stimuli

Visual stimuli were computer-generated black and white checkerboard patterns presented over the video monitor (Panasonic 14-inch Model WV 5400). Binocular visual field stimulation was about 9 degrees visual angle. Each check subtended about 17 minutes visual angle. Average background luminance was about 0.3 ftL and target luminance was about 5 ftL. The patterns were presented aperiodically with interstimulus intervals averaging about 2 seconds (1.0-3.0 seconds).

Auditory clicks were presented binaurally over headphones (Sennheiser Model 424X) aperiodically about every 2 seconds (1.0-3.0 second interstimulus intervals). Click intensity was about 65 dB (A) (Bruel and Kjaer Impulse Sound Level Meter, Model 2209, One-Third Octave Filter Set, Model 1616). Headphone leads were shielded to minimize click artifacts.

Bimodal presentation included simultaneous presentation of the visual and auditory stimuli. These stimuli were presented aperiodically about every 2 seconds (1.0-3.0 seconds).

During all recording periods, white noise was used for masking. It was presented to the subjects through the headphones and via a speaker in the sound chamber at a level of approximately 50 dB (A). This was done to create more uniform data acquisition conditions across all the subjects. The auditory click stimuli were presented over this background noise.

Procedure

Recording Sites

Eight channels of visual, auditory, and bimodal ERP data were acquired from four pairs of homologous sites: Sites F3 and F4 over the frontal brain region, an association area; sites T3 and T4 over the temporal region, a primary auditory reception area where many visual and auditory nerves interconnect; sites P3 and P4 over the parietal region, a primary association area; and sites O1 and O2 over the occipital region, a primary visual reception area. Ground was at Pz in the mid-parietal area. Sites designated by odd numbers denote left hemisphere locations; and those designated by even numbers, right hemisphere locations.

[1]Identification of the equipment is for documentation only and does not imply endorsement.

Electrodes

The subjects were prepared for recording after they had received brief instruction, completed a brief background questionnaire, and signed a privacy act and volunteer consent form. An elastic helmet (Lycra) fitted with plastic holders for the electrodes was placed on the subject's head. Each subject's hair was parted and scalp cleaned with an alcohol-impregnated cotton swab that was placed through the holders. Electrode cream was placed down the holders and rubbed into the scalp. The electrodes were silver/silver chloride Beckman miniatures (actual surface contacting area was 2 mm) with a clear plastic extension tube (38 mm long) attached and filled with electrolytic solution. A small sponge (microcell foam) soaked with electrolyte held the solution in the tube and made contact with the electrode paste on the scalp. The extension tube not only held the electrode in place but also minimized the slow potential drift due to scalp temperature change that would have otherwise been picked up at the recording site. A Beckman mini-electrode fitted with a standard two-sided adhesive wafer served as a reference electrode on the nose.

The helmet and all 10 electrodes could be attached in 6-8 minutes with impedance readings of 2-3K ohms. After all electrodes were in place, the subjects were instructed to observe their real-time EEG activity on the oscilloscope display. They were then instructed to move their jaws, eyebrows, etc. so that they could observe how muscle artifacts could contaminate the ERP data. The subject was then seated in a sound chamber in alignment with the video monitor. A hand-held switch allowed the subject to suspend all stimulus presentation and analysis operations to eliminate artifact. Additional artifact rejection was available by the console operator prior to storing the data.

Event-related Potential (ERP) Data

ERPs were generated on-line, and the analog-to-digital (A/D) sampling speed was one-quarter million samples per second. The visual and auditory ERP data were retrieved from a floppy diskette and the required computations were performed. The data were then displayed on the video monitor and hard copies were obtained. Bimodal ERP data were also computed and displayed in a similar manner.

Eight channels of visual and auditory ERP data are overlaid in Figure 1. Root mean square (RMS) and standard deviation (SD) amplitude values are presented, along with the waveform means values for the half-second post-stimulus epoch (533 msec). SD amplitude values (in microvolts (μV)) are normalized (waveform mean set to zero) RMS values (in μV). Only SD amplitude values (in μV) were used for the analyses. These values have been found to be very effective when employing ERPs to study individual differences among many different kinds of subjects. There are individuals who do not manifest clearly defined ERP components. This index is also advantageous in that it permits the description of ERP amplitude as a single value (Callaway, 1975; Lewis & Froning, 1981). Prestimulus waveforms (133 msec) were also recorded and displayed for each channel. Calibration, polarity, DC offset, time base, and other descriptive information were also displayed. The waveforms in the left column were derived from the left hemisphere (LH). The waveforms from top to bottom were from the front to the back of the head at frontal, temporal, parietal, and occipital sites (F3, T3, P3, O1). Right hemisphere (RH) ERP data from sites F4, T4, P4, and O2 are represented in the right column.

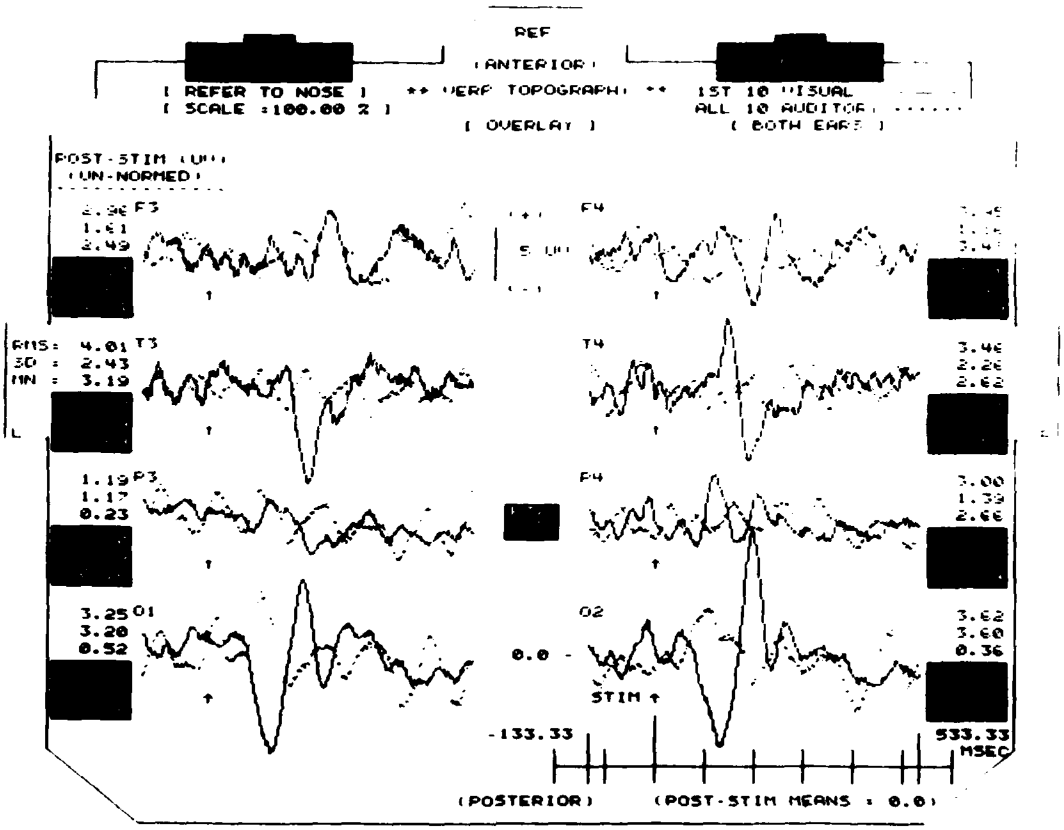

Figure 1. Sample VERP and AERP data. The left column of data is from the left hemisphere; and the right column, from the right hemisphere. From top to bottom, the records are from the frontal, temporal, parietal, and occipital regions.

In addition to the directly recorded ERP amplitudes, an index was derived to reflect a hypothesized property of brain behavior. To assess the relative functioning between the hemispheres, ERP asymmetry measures were examined between homologous electrode sites. An asymmetry index was defined as the right- minus left-hemisphere amplitude (RH-LH) for a specific brain area. If this expression is positive (negative), there is a decrease in activity at the left (right) hemisphere site, which indicates increased information processing within that particular location.

Statistical Analyses

The relationships betwen asymmetry measures and cognitive characteristics were examined by computing an exploratory principal-factor analysis without iteration to determine the independent dimensions that account for a considerable amount of the underlying variability of these indices. This initial factor solution was rotated according to the varimax procedure to achieve a simpler structure and a more meaningful pattern. Rules of thumb for achieving the simplest factor structure and more theoretically meaningful factors have been summarized by Harman (1967, p. 98). Rummel (1970), when ruminating over the proper ratio of the number of cases to variables for factor analyses, makes the distinction between interest in describing data and inferencing from sample results to population factors. In the first case, Rummel maintains that a factor analysis will describe the data adequately even if the number of variables is larger than the number of cases. In the second case, he asserts that a factor analysis will yield a valid inference from sample to universal factors only if the number of cases is larger than the number of variables. Rummel (1970, p. 220) mentions that "determining what the minimum allowable ratio of cases to variables is a matter of research taste." In the study discussed herein, the prime interest was in describing the variability common to brain asymmetries and cognitive attributes--not in generalizing to universal factors. Consequently, it seemed reasonable to employ 23 variables (12 asymmetry measures and 11 cognitive attributes) and 50 cases for factor analysis.

RESULTS

The descriptive data for cognitive characteristics and ERP asymmetries are presented in Table 2. The results obtained from rotating the principal-factor solution according to the varimax procedure are tabulated in Table 3. Eight significant factors accounted for 74.4 percent of the variance. The terminal factors, in order of diminishing percentages of the variance accounted for, are described below.

1. Factor 1 was characterized by auditory and bimodal asymmetries in the frontal, temporal, and parietal areas.

2. Factor 2 was characterized by visual and bimodal asymmetries in the temporal and parietal areas.

3. Factor 3 was a cognitive dimension characterized by VERBCOMP, GENRAPTD, LOGIREAS, REFLIMPL, VISUAL, and READCOMP.

4. Factor 4 was characterized by visual and bimodal asymmetries in the occipital areas.

5. Factor 5 was characterized primarily by TOLRAMBQ, CATEWIDH, GENRAPTD, SPACPERC, and LOGIREAS and secondarily by bimodal asymmetry in the parietal regions.

6. Factor 6 was characterized by visual and bimodal asymmetries in the frontal areas and by READCOMP.

7. Factor 7 was characterized primarily by auditory asymmetry in the occipital regions and FILDINDP and secondarily by SPACPERC and CATEWIDH.

8. Factor 8 was a cognitive dimension characterized by CONCSTYL, COGCOMPX, SPACPERC, READCOMP, and LOGIREAS.

Factors 1, 2, and 4, defined primarily by brain asymmetry measures, jointly accounted for approximately 32 percent of the variance. Factors 3 and 8, characterized chiefly by psychometric measures of abilities, aptitudes, and cognitive styles, together accounted for about 18 percent of the variance. Factors 5, 6, and 7, specified by brain asymmetry and cognitive psychometric measures, accounted for approximately 24 percent

Table 2

Descriptive Data for Cognitive Characteristics and ERP Asymmetries

Characteristic	$\bar{X}$	SD
Cognitive Style		
FILDINDP	4.40	3.28
CONCSTYL	11.70	4.18
REFLIMPL	5.44	3.84
TOLRAMBQ	5.82	2.26
CATEWIDH	30.00	11.13
COGCOMPX	73.66	21.98
Aptitudes and Abilities		
GENRAPTD	63.50	18.67
READCOMP	10.59	1.96
VERBCOMP	6.74	2.51
VISUAL	28.34	16.76
LOGIREAS	.48	4.02

ERP Index / Hemisphere / Electrode Site	Visual ERPs		Auditory ERPs		Bimodal ERPs	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Asymmetries						
Right Minus Left Hemisphere						
Frontal	.05	.67	.04	.55	-.15	.76
Temporal	.36	.80	-.04	.85	.36	.96
Parietal	.25	.75	-.15	.75	.04	.91
Occipital	-.21	.88	-.24	.64	.01	.96

Notes.

1. N equals 50.
2. $\bar{X}$ values are in standard deviation microvolts.

Table 3

Varimax-factor Matrix for the Brain Asymmetry Measures and Cognitive Characteristics Data

Measure	Factors 1	2	3	4	5	6	7	8
Visual Asymmetry								
Frontal	.00	.11	.10	.00	.15	.86	.09	.07
Temporal	.01	.81	-.15	.00	.17	.24	.01	-.03
Parietal	.07	.86	.05	.13	-.05	.00	.17	.14
Occipital	.02	.21	.03	.86	.06	-.08	.11	.03
Auditory Asymmetry								
Frontal	.82	-.12	.15	.20	.09	.05	-.13	.02
Temporal	.86	.27	-.12	-.01	.02	.05	.08	-.01
Parietal	.75	.37	-.07	-.21	-.10	.04	.30	-.18
Occipital	.12	.17	-.06	.14	.14	-.01	.77	-.14
Bimodal Asymmetry								
Frontal	.41	.04	-.16	.07	-.15	.67	-.17	.22
Temporal	.36	.70	-.01	.36	-.11	.06	-.03	-.01
Parietal	.48	.57	.12	.15	-.51	-.14	.03	.00
Occipital	.05	.08	.10	.91	-.05	.07	.04	.08
Cognitive Style								
FILDINDP	-.09	.01	.30	.00	-.05	.17	.74	.22
CONCSTYL	-.26	.08	.22	.08	.13	.04	.12	.74
REFLIMPL	.03	-.04	.52	-.26	-.16	.31	.19	-.06
TOLRAMBQ	.10	-.02	.05	.04	.67	-.09	.22	-.08
CATEWIDH	-.12	.05	.19	-.08	.61	.19	-.33	-.01
COGCOMPX	.13	.04	-.25	.03	-.22	.09	-.08	.72
Aptitude and Ability								
GENRAPTD	-.08	-.02	.64	.18	.50	-.10	.28	.18
READCOMP	.12	-.21	.38	.09	.17	-.58	-.22	.35
VERBCOMP	-.02	-.03	.85	.20	.06	-.15	.07	.07
VISUAL	.13	-.03	.39	.16	.44	-.25	.39	.40
LOGIREAS	.00	.02	.61	-.04	.35	.01	-.19	-.35
Associated Eigenvalue	2.71	2.59	2.43	2.03	1.91	1.89	1.86	1.70
% Variance Accounted for	11.78	11.24	10.58	8.81	8.32	8.21	8.10	7.37
Cumulated % Variance	11.78	23.02	33.60	42.41	50.73	58.94	67.04	74.41

Note. Only factors with asociated eigenvalues greater than or equal to 1.0 are tabulated. This minimum eigenvalue criterion may ensure that only factors accounting for at least the amount of total variance of a single variable are significant.

of the variance. These statistics imply that a major portion of the variability in the data was attributed to brain asymmetry measures either acting independently (32%) or interactively with cognitive measures (24%). Factors 5, 6, and 7 suggest that some ERPs and cognitive characteristics contribute to or define the same underlying independent dimensions. That is, they weight the same factors, implying that they are related.

Some of the results of the varimax rotation seem to indicate that complex cognitive processing, as indexed by TOLRAMBQ, CATEWIDH, GENRAPTD, VISUAL, LOGIREAS, and FILDINDP, is statistically linked with visual, auditory, and/or bimodal cerebral asymmetries in the frontal, parietal, and/or occipital areas.

DISCUSSION AND CONCLUSIONS

Very little empirical data have been obtained to support the ATI idea consistently (Berliner & Cahen, 1973; Boutwell & Barton, 1974; Bracht, 1970; Bracht & Glass, 1968; Cronbach & Snow, 1969, 1977; Roberts, 1968-69). Bracht (1970) surveyed and analyzed 90 ATI studies that (1) compared two or more alternative instructional treatments designed to attain the same educational objectives, and (2) included one or more personological variables for evaluating different treatments at distinct values of these variables. He scrutinized 108 ATIs in these studies, but found only five had significant disordinal interactions. Of these, just one included an educationally related personological variable; namely, under- or overachievement. Bracht drew two general conclusions from his review:

1. No available data demonstrate conclusively that personological measures of general ability and achievement are useful for discriminating among alternative instructional treatments for students within the same age range.

2. No analyses seem to have been conducted, before studying ATI effects, of the different kinds of information processing elicited in the students by the teaching treatments themselves.

Consequently, these experiments typically assessed ATI effects as an afterthought, and personologial variables were not considered in an information-processing frame of reference.

Cronbach and Snow (1969) reported an extensive and systematic analysis of many of ATI's ramifications. They concluded, as Bracht did, that ATI effects are seldom established empirically; that is, significant disordinal interactions have been found and reported infrequently. They suggested that these negative results could be due to the psychometric development of the aptitude measures for selection purposes rather than for learning-performance purposes. Possibly, the instructional treatments were too poorly conceived and implemented for them to interact with learning and performance processes. Roberts (1968-69) reviewed the literature for ATI results and inferred that (1) the consequences of ATI are indeed complex, and (2) the incorporation of practice effects makes the phenomenon even more complex. The majority of reported ATI studies have been conducted in the laboratory using artificial learning tasks, thus precluding valid generalization to the real classroom. Before such generalization can be made, more ATI investigations must be conducted using more appropriate learning materials. In most of the ATI studies surveyed, an extremely large battery of aptitude tests has been administered. Although these psychometric instruments may have had moderate reliabilities and significant correlations with performance measures, the practical use of the battery is precluded. Therefore, individualized instruction based upon aptitude tests seems to have been restrained, since most ATI investigations have not had any important impact upon the classroom. The promises of the ATI idea have not been fulfilled; it has been almost impossible to extrapolate research results into useful adaptive instructional systems (Boutwell & Barton, 1974; Gage & Unruh, 1967). Apparently, the usefulness of the ATI construct is still to be demonstrated (Tobias, 1976).

Cronbach and Snow (1977) reexamined the ATI literature to gather additional evidence concerning the existence of the ATIs and to identify ATI hypotheses worthy of further study. The major impetus driving investigations of ATIs has been the idea that valid policy decisions regarding student placement and adaptive instruction could be derived from established ATI generalizations. However, the ATI literature is plagued by inconsistencies that preclude appropriate extrapolations. The only trend in the literature seems to be that many of the findings of ATI studies are incompatible. Consequently, it is difficult to make sound recommendations regarding adaptive instructional procedures. No ATIs have been substantiated to the extent that they can be used unequivocally as prescriptions for accommodating instruction to student characteristics. Also, the majority of ATI studies suffer from lack of replication or generalization. Although some ATIs have been empirically established, they have not been corroborated. In other investigations, either ATIs have not been demonstrated or the results could not be interpreted, thus emphasizing the elusiveness of ATIs.

In their latest survey, Cronbach and Snow (1977) discovered that general abilities--for example, measures of scholastic aptitude, nonverbal reasoning, and intelligence--are correlated with the rate of learning and/or the amount learned. Some ATIs were established using measures of general abilities. High general ability students thrive in instructional environments in which they can process the material to be mastered according to their own needs; low general ability students tend to perform poorly in such situations. Attempts to establish ATIs using specialized abilities--for example, spatial and mathematical abilities--have been abortive and not suggestive of useful adaptive instructional strategies. Some ATIs have employed various personality traits and styles--for example, the need for achievement and affiliation and for constructive and defensive motivation. However, existing evidence is too scattered to allow unquestionable interpretations and confident conclusions. Contrary to what may be expected, ATI research has not demonstrated that low-ability students who use programmed instruction acquire as much knowledge as high-ability students who do not. Likewise, few ATIs have been established that make instruction less verbal for students low in this specialized ability. Inconsistencies are readily apparent in the findings of studies that sought ATIs using selected indices of cognitive skills and structures; for example, associated memory, induction/deduction, and conceptual level. Attempts to demonstrate the existence of ATIs employing dimensions of personality such as anxiety, introversion, and motivational variables have led to the belief that these interactions (1) are very complex, being mediated by other salient student characteristics, and (2) are unlikely to be accounted for by a single generalization. Similarly conflicting results are routinely encountered regarding ATIs involving student personality variables and different learning environments and instructor styles. Consequently, it appears that no dependable extrapolations can be made for adaptive instructional purposes.

Since customary methods employed for experimenting with ATIs have not been very successful in producing prescriptive procedures for adapting teaching treatments, it seems reasonable to seek alternative approaches for accommodating instructional strategies to individual differences that exist among students (Federico, 1980). A few of the findings from the effort reported herein implicated that some hemispheric asymmetries are associated with certain cognitive attributes. These results established the construct validity of specific cerebral asymmetries as indicators of particular cognitive styles, abilities, and aptitudes. The findings also demonstrated that, at least for this specific sample, brain asymmetries accounted for more of the variability among the subjects than did cognitive attributes. This established the importance of lateral asymmetries as individual difference measures. For both of these reasons--their proven construct validity with respect to certain cognitive characteristics and their importance as individual difference indices--cerebral asymmetries can be considered "aptitudes" within an ATI framework. Even though this has been empirically established, an important theoretical and practical question still remains to be answered: How can this asymmetry information be used to design and develop differential teaching treatments to produce ATIs for prescribing adaptive instructional strategies to optimize student learning?

One simplistic possible approach is suggested by the following. Lateral hemispheric specialization of the brain has been employed as a physiological indicator of two different modes of cognitive style: dominant manners of information processing that people typically employ when perceiving, learning, problem solving, or decision making. A verbal, analytic, sequential, and syllogistic mode of information processing has been associated with left-hemisphere activity for most right-handed individuals; and a spatial, synthetic, simultaneous, and intuitive mode, with right-hemisphere activity. Similarly, cognitive style has been related to patterns of lateral asymmetry: Typically, for people performing verbal-analytic tasks, the alpha-wave or idling rhythms over the right hemisphere usually increase; on spatial-synthetic tasks, the alpha-wave or idling rhythms over the left hemisphere usually increase. The presence of the alpha or idling rhythm is an index of the diminution of information processing within that hemisphere. Some individuals predominantly employ the verbal-analytic cognitive style for problem solving and decision making, whereas others predominantly employ the spatial-synthetic cognitive style for such tasks (Doyle, Ornstein, & Galin, 1974; Galin, 1975; Galin & Ellis, 1975; Galin & Ornstein, 1972).

Students' difficulty in mastering certain material or in performing a particular task may be due to their inability to adopt the appropriate mode of information processing. Since laterality data may provide useful procedures for assessing preferred cognitive styles, it may be possible to ascertain which information processing modes facilitate the learning and performing of a task and which modes interfere. It may be feasible to train students whose predominant cognitive style is verbal-analytic to adopt a spatial-synthetic orientation when appropriate, and vice versa. Alternatively, instructional strategies themselves could be adapted to conform to a student's preferred cognitive style; that is, initial learning and subsequent performance could probably be enhanced by presenting material in the medium that is most congruent with a student's major mode of information processing. For verbal-analytical individuals, acquisition, retention, and retrieval may be facilitated by employing a primarily verbal medium. For spatial-analytically inclined individuals, those same functions may be facilitated by employing a primarily visual medium.

The results that have been gained by using averaged evoked potentials' sophisticated computer-aided techniques have led researchers to conceptualize cerebral activity during learning and memory as more than simply localized to specific regions of the brain. Instead of the place analog of human information processing, which is implied in the lateral hemispheric specialization of the cortex, several investigators (Bartlett & John, 1973; John, 1972, 1975; John, Bartlett, Shimokochi, & Kleinman, 1973; John & Thatcher, 1976; Thatcher, 1976; Thatcher & April, 1976; Thatcher & John, 1975) have hypothesized that all cortical structures are equipotential for any specific function. However, these sites vary according to their own "signal-to-noise" ratios for each specialized action.

In this context, "noise" signifies the random electrical activity of a cerebral neuron, and "signal" signifies the synchronous electrical activity of a cerebral neuron firing in rhythm with other functionally similar neurons. Practically every region of the brain contributes to many different functions, but the greater the signal-to-noise ratio of a particular region, the more that area is involved in a particular action. Structures traditionally thought to control a specialized function are actually those with the highest signal-to-noise ratio for that activity. This speculation regarding brain activity has been referred to as statistical configuration theory. According to this theory, it is not the localization of excitability that matters (e.g., left-versus-right idling cerebral hemisphere) but, rather, the rhythm of activity of one area relative to another; that is, various regions of the brain combine statistically to produce cognitive output. The rhythm of their average firing rate determines the nature of the cognitive function. Even memory for a certain event or fact is physiologically encoded at a frequency-specific activity of the entire brain rather than being mapped on a particular region.

Research should be conducted to determine the feasibility of using this equipotential model for suggesting alternative teaching strategies. Possibly, instructional treatments could be accommodated to conform to a learner's preferred mode of information processing as specified by computer-based average evoked potential techniques. The equipotential paradigm of cerebral function, together with the necessary advanced technology, could be employed to adapt instruction to the dynamic state variables of different students. In a computer-based, individualized, and interactive instructional environment of the future, physiological indicators could be monitored within-task to permit a more refined manipulation of teaching treatments. Within-task indicators, as well as pretask physiological parameters, should be more objective and unbiased indices of cognitive processing than are traditional psychometric tests of abilities and aptitudes.

Probably both cerebral hemispheres contribute to complex cognitive activities (e.g., verbal comprehension, problem solving, art appreciation). It has been proposed, though, that left and right hemispheres are themselves specialized, respectively, for serial vs. parallel processing, analytical vs. global reasoning, digital vs. analog symbolizing, verbal vs. imaginal encoding, etc. Within this scheme, the left hemisphere outperforms the right in serial, analytical, digital, and verbal processing; the right outperforms the left in parallel, global, analog, and imaginal processing. Given the present state of knowledge, it is not certain which of these dichotomies is truly basic, fundamental, or prime, in the sense that it is essential to the comprehension of the others. Contributing to this perplexity is the unprecise conceptual and operational definitions typically attributed to both ends of these alleged dichotomies. An important theoretical problem then is the true nature of cerebral lateralities. Accompanying this issue is another involving the degree of absoluteness or partiality with which the hemispheres can perform different functions. Some speculation implies that a hemisphere that is not dominant for a specific type of processing may not execute a certain task at all. Also, another important conceptual problem that must be resolved deals with the degree of cooperation, division of labor, and time sharing between the hemispheres in performing complex cognitive tasks (Helligie, 1980).

Allen (1983) discussed "cooperative interaction models" of cerebral laterality. These paradigms presume that both hemispheres can execute a given function either equally or unequally well. At issue is not whether half of the brain can perform a process, but when it actually contributes to the function. Most of these models maintain that the hemispheres process simultaneously and interact positively. Output is proposed to be a joint product of both halves of the brain. Other interpretations suggest that the two hemispheres are (1) processing in a similar manner with overall performance resulting from their interaction or (2) producing distinct and necessary functions with overall performance resulting from their dynamic coordination of subprocesses. The essential notion of these dual conceptualizations is that cooperative interation is crucial to performance output, but they do not propose the same degree of participation from both hemispheres. The most popular paradigm postulates that one half contributes more than the other to a specific performance with the necessary communication between them being via the corpus callosum, cerebral commissures, and/or brain stem mechanism.

The cooperative interaction model seems to be the most likely of the hemispheric asymmetry hypotheses. Both halves of the brain are more than generously connected cortically as well as subcortically, thus providing at least some mechanisms for communication between them. Also, the fact that individuals can execute very skilled perceptual and motor tasks involving both sides of the body in speedy, simultaneous, and coordinated performances suggests that both hemispheres are acting in a cooperative manner. Many experimental methods (e.g., visual fields, dichotic listening, hemispheric blood flow, event-related potentials) permit the monitoring of left and right side of the brain and body at the same time. Findings based upon these techniques also indicate that both hemispheres manifest some activity that provides circumstantial evidence for cooperative interactions between both sides of the brain (Allen, 1983; Bryden, 1982; Helligie, 1980; Hillyard & Kutas, 1983).

Allen identifies two different types of cooperative interactions models: (1) an additive version where both hemispheres are executing identical functions with overall output produced by the vector sum of their activity, and (2) an integrative version where each half of the brain instantaneously performs different processing components that are unified to culiminate in the final action. Considering the degree of lateralization and mechanism of cooperative interaction, one unlikely interpretation is that the former may be an all or none phenomenon. It is more reasonable to think of lateralization as a continuum or dimension along which individuals and psychological processes may vary.

Conceptually distinct from cooperative interaction models are negative interaction models of hemispheric asymmetry. These propose that both sides of the brain can execute certain functions; howeer, they typically suppress or inhibit the activity of the other through cortical or subcortical mechanisms. Some of these paradigms postulate unidirectional inhibition (i.e., one of the hemispheres suppresses the other but not vice versa); others postulate bidirectional inhibition (i.e., both hemispheres mutually or reciprocally suppress each other). In addition to proposing that the left hemisphere inhibits the right for verbal functions, Bogen (1969) maintained the complementary notion that the right hemisphere may inhibit the left during spatial functions. It has been suggested that each side of the brain can suppress the other and also that the cerebral commissures actually functionally disconnect each hemisphere from the other. Consequently, either side of the brain can process information independently of the other (Galin, 1974). The unidirectional inhibition model maintains that a difference maximizing mechanism minimizes interhemispheric interference; whereas, the bidirectional inhibitional model maintains that a difference minimizing mechanism is advantageous whenever processing requirements demand a balancing of hemispheric functioning (Allen, 1983).

Theoretical or conceptual problems, in addition to methodological difficulties, may limit the practical payoffs from ATI and asymmetry research. Possibly, the implicit assumption that instructional treatments can be accommodated to students on the basis of cerebral lateralities is in error. If the correct technique is to adapt instruction more minutely and dynamically, asymmetry measures similar to traditional aptitude indices for discriminating among students may be inappropriate for finer and more continuous prescriptions. Most aptitude tests have been designed and developed to predict student performance under fixed macropretask teaching treatments and not within changing microadaptive instructional systems (Boutwell & Barton, 1974).

One conceptual difficulty that may afflict asymmetry and ATI investigations is that the nature of the many possible interactions between cerebral lateralities and alternative teaching treatments is troublesome to theorize. If instructional treatments differ only slightly, it may be difficult for them to interact differentially with asymmetry measures, and vice versa. The alternative abilities model (Tobias, 1976) that forms a theoretical framework for ATI research has been undermined by such methods. Alternative instructional treatments that are not distinct probably would not require significantly different cerebral activity from students for optimal performance. An important restriction that may be extrapolated from the alternative abilities model for ATI investigations is that, even if different instructional treatments are designed and developed to draw on different asymmetries, the cerebral lateralities may not be exclusive.

Another distinct difficulty intrinsic to considering cerebral asymmetries as individual measures for ATIs is extracted from the idea that different cognitive attributes contribute more or less to performance at distinct stages of learning (Burns, 1980; Federico, 1983; Fleishman & Bartlett, 1969; Roberts, 1968-69; Tobias, 1976). The relationship between aptitudes and acquisition is complex since, in the course of learning, it usually fluctuates as a function of when achievement measures were obtained. This phenomenon further compounds the predictability of learning behavior using cognitive attributes because the mental processes demanded by a task typically change with practice. Therefore, the instructional treatments designed to teach the task would have to change during acquisition. This might prohibit the development of different teaching treatments that are a function of not only individual aptitude indices but also distinct asymmetry measures. The extent to which these different instructional strategies require distinct cerebral lateralities will likely change over the course of acquisition. The design, development, and utilization of alternative instructional treatments may not be theoretically possible, practically implementable, and economically feasible.

An important issue regarding the hemispheric asymmetry ATI formulation is whether or not specific patterns of cerebral lateralities will be equally critical for acquiring distinct content areas. If established ATIs are content-limited (Nuthall, 1968; Tallmadge & Shearer, 1969, 1971), then these interactions may have only slight practical and theoretical utility. Little can be deduced concerning useful and optimal instructional treatments from one subject matter to another when ATIs are content-specific. Restricted generality across subject matters is not conducive to speculation among researchers regarding possible ATIs in other content areas. Therefore, a subject-matter particular, hemispheric asymmetry ATI model may be more of a task-by-instructional-treatment paradigm with cerebral lateralities accounting for very little variance. Also, another potential and paramount problem in asymmetry ATI investigations is the possible confounding of content with teaching treatment. At times, it may be difficult to determine whether the reported interactions are between cerebral lateralities and instructional treatments or between brain activity and subject matter.

A final difficulty of the hemispheric asymmetry ATI paradigm is that it may be impractical to design and develop distinct instructional treatments to interact with cerebral lateralities. The many models of hemispheric asymmetry add to the difficulty of deciphering how to employ these paradigms intelligently for planning and producing prescriptive pedagogical strategies. The number of conceptual problems identified and discussed above also contribute to the confusion. The lack of consistent and categorical results and conclusions concerning cerebral laterality research lend to the ambiguity around asymmetries. Lastly, the actual experimental methodology employed for recording and producing hemispheric asymmetry measures is extremely important. Quite small and apparently irrelevant details can be very vital to the derivation of cerebral lateralities as well as other brain electrophysiological parameters (e.g., recording montage; type of electrodes used; particular electrode paste applied; uncontrolled polarization of electrodes; main voltage flunctuations; subject movement, expectancy, and arousal; intensity, nature, and spacing of stimuli; artifact rejection techniques; analog-to-digital sampling speed or digitation rate; masking or background noise; and component breakdown) (Eysenck & Barrett, in press). To employ hemispheric asymmetries as individual difference measures for establishing ATIs may really be at this time the seeking of truly elusive interactions as well as science fiction.

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